7-1900

Bulletin No. 71 - Carrying Capacities of Irrigation Canals

Samuel Fortier

EXPERIMENT STATION

—OF—

THE AGRICULTURAL COLLEGE

OF UTAH.

Bulletin No. 71.

Carrying Capacities of Irrigation Canals.

BY SAMUEL FORTIER.

JULY, 1900.

LOGAN, UTAH.

PRESS OF SMITH, CUMMINGS & CO.,

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THE CARRYING CAPACITIES

—OF—

IRRIGATION CANALS.

BY SAMUEL FORTIER.

During the summer of 1897 the writer was enabled to make, with the help of his assistants, T. H. Humpherys, A. P. Stover, and W. D. Beers, a number of experiments on the carrying capacities of irrigation ditches and canals. The funds necessary to carry on these investigations were provided by the U. S. Geological Survey and the Agricultural Experiment Station of Utah. Shortly after the field work was completed the writer resigned his position with the College to accept that of chief engineer and superintendent of the Ogden Water Works and the Bear River Canal System, and his time has been so fully occupied since with other duties that he has not had, until now, an opportunity to compile the information collected two and one-half years ago and put it in shape for publication.

About sixty experiments were made on irrigation channels, which varied in size from the small ditch carrying a few miner's inches to the large canal carrying 225 second feet.

Experiments were made on nearly every form of ditch common to Western America, and included many of the

crudely formed ditches of the Mormon pioneers, made nearly forty years ago, as well as the more modern and better designed canals of the Bear River Canal System. The object sought was to ascertain as accurately as possible the existing conditions of ditches and canals that had been in operation for a number of years. In order to obtain the volume which flowed in any particular ditch and compare it with some well known empiracal formula, such as Kutter's or Chezy's, it was necessary to ascertain the slope of the surface of the water, the sectional area of the water, the mean velocity and the ratio between the water area and the wetted perimeter. This additional information regarding the form which channels assume after being acted on by water and the atmosphere is valuable in that it gives the builder of a new canal some idea of the proper form to adopt.

In the discussions which follow, the hydraulic elements, whether obtained in the field or computed from data taken in the field, have been referred to those two well known formulae, viz: Chezy's and Kutter's.

The conduits and irrigation canals of the West have been designed in so far as their carrying capacities were concerned, in accordance with Kutter's formula. It is, therefore, proper that experiments on the flow of water in canals should be compared with that formula.

Herr Kutter did not live long enough to adopt his formula to American practice, and particularly to American irrigation practice. His values of the coefficient of roughness (n) were confined to six different classes of channels, viz:

Class 1. n=.010 for carefully planed boards or smooth cement.
Class 2. n=.012 for common boards.
Class 3. n=.013 for ashler masonry.
Class 4. n=.017 for rubble masonry.
Class 5. n=.025 for channels in earth, brooks and rivers.
Class 6. n=.030 for streams with detritus and aquatic plants.

It will be noted that of these six classes only one applies to irrigation canals. Besides, the mode of building and the character of the materials were different from those which

prevail in America, and these differences would no doubt exert some influence on the derived results.

However, the late P. J. Flynn, M. Am. Soc. C. E. of Los Angeles, California, took up the unfinished work of the noted Swiss engineer, and by his labors adapted the experiments of Ganguillet and Kutter, as well as other hydraulicians, to American practice. Mr. Flynn's tables on the flow of water in open and closed channels have materially lessened the labors of every American hydraulic engineer, and his values for the coefficient of roughness (n) have been considered safe guides during the past ten years.

One of the objects which the author had in view in making his experiments was to compare the results, and particularly the values of the coefficient of roughness (n) with those given by Mr. Flynn for canals in similar conditions.

The field work consisted in selecting a suitable portion of the canal to be investigated, writing a brief description of the prevailing conditions, and ascertaining its discharge in second feet, the slope of the water surface, the sectional area and the wetted perimeter. The office work consisted in computing from the data taken in the field the mean velocity, hydraulic mean radius, coefficient of roughness (n) as given in Kutter's formula, and the general coefficient (c) as given in Chezy's formula where $V=C\sqrt{RS}$.

Measuring the Discharge.

The discharge was measured either by a current meter or by a trapezoidal weir. The trapezoidal weir designed by the Italian engineer Cesare Cippoletti, was preferred to the Francis rectangular weir on account of the simplicity of calculation as well as possibly greater accuracy. The one general equation used in all weir calculations was $Q=3.367\ L\ H^{\frac{3}{2}}$, where Q equalled the discharge in second feet, L the bottom length of the weir in feet and H the depth of water in feet over the crest of the weir. The conditions necessary for accurate measurement were carefully observed, such as low velocity of approach, a free fall, complete contraction on the bottom and sides, and a close measurement of the head of water over the weir.

In determining the discharge by means of the current

meter the results were not so accurate, but in every case from three to six separate and distinct current meter measurements were taken, and it was thought that the mean of all these measurements would not vary far from the actual discharge. At the close of the field work the current meter was carefully re-rated at the rating station on the Potomac River, and the new rating table was used in the calculations of all velocities of flow in canals tested.

Obtaining the Average Cross Sections.

This was obtained by plotting in different colors on a large scale the three or more cross sections taken in the field. A new perimeter was then adopted which represented the average of all those plotted. Its length was found by a pair of dividers, and the area of the average section by a planimeter. The depths of water given in the tables represent those of the average section, but approach very nearly to an average of all those taken in the field at any one point.

The Slope of Water Surface.

The slope of a canal represented by the fall of a given portion, usually from 50 to 300 feet, divided by the distance, was determined by a new Buff and Berger 18 inch level, and a leveling rod reading to thousands of a foot. The slope of a water surface is difficult to obtain with accuracy for the reason that in nearly all channels there are pulsations like the heart beats of nature, which cause the surface to rise and fall. Again, in irrigation canals long in use, the water grade, owing either to abrasion or sedimentation, is seldom uniform and the flow of water in any comparatively short portion is more or less influenced by the velocity in the section above. If one portion 100 feet in length had a fall of four feet per mile, and another portion just below a fall of three feet per mile, the influence of the steeper grade in the higher portion would be felt on the lower. One could partially eliminate this source of error by taking a long distance as a test, but this would introduce greater errors due to alignment and diversity of cross sections. The method followed in determining the slope was to drive small finishing wire nails into the tops of submerged oak stakes at each end of the section to be

tested. It was not always possible to have the top of the nail coincide exactly with the surface of the water, but this difference introduced no error in the results, provided the heads of both nails occupied the same relative position to the surface of the water. In the case of pulsations or slight waves caused by winds, the tops of both nails were even with the highest or lowest water surfaces. This method under ordinary conditions will give as accurate results as those obtained by hook guages.

Coefficients.

Having obtained all the hydraulic elements either from data taken in the field, or calculations made in the office, the coefficients (C) in the Chezy formula and (n) in the Kutter formula, were then computed and checked.

Experiment No. I.

This test was made on the Providence Canal from Logan River, and the bed was composed of gravel about the size of peas with other particles about the size of small walnuts scattered about. There was no vegetation, and the discharge was found by taking the average of the meter measurements given below.

Upper measurement	10.21	second	feet
" measurement	9.95	"	"
Middle measurement	9.86	"	"
Middle measurement	10.20	"	"
Lower measurement	9.75	"	"
" measurement	9.93	"	"
Average	9.98		

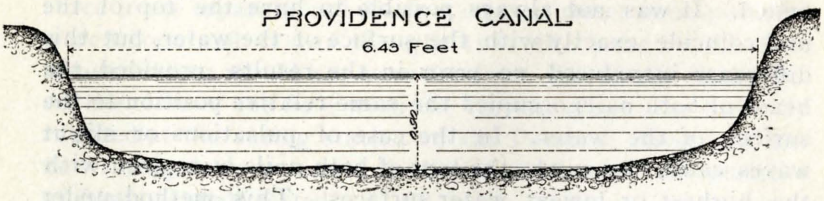

TABLE NO. 1.

Mean Cross Section.				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00			Slope in Feet per foot	0.00175 feet
0.25	0.63			Slope in Feet per 100 ft	0.175 "
1.00	0.82			Slope in Feet per mile	9.240 "
2.00	0.87			Mean discharge	9.984 sec. feet
3.00	0 90			Wetted perimeter	7.400 lin. feet
4.00	0.90			Area of water section	5 258 sq. feet
5.00	0.87			Mean velocity	1.898 lin. feet
6.00	0.63			Hydraulic mean radius	0.710
6.43	0.00			Coefficient of roughness (n)	0.02376
				" C in $V=C\sqrt{RS}$	53.845

Experiment No. 2.

This test was made on a sixty foot length of Affleck's mill race, Logan, Utah. The general form of cross section is shown in Fig. 2, and the channel was composed of gravel, ranging in size from small particles to others one-half inch in diameter, with an occasional pebble two inches in diameter. The sides were in fair condition, with some weeds near the edges which did not interfere to any appreciable extent with the flow of water. The discharge was obtained from the mean of the following measurements, which were made by a current meter.

Upper measurement	15.152	second	feet
" "	15.360	"	"
Middle "	15.574	"	"
" "	15.870	"	"
Lower "	15.283	"	"
" "	14.836	"	"
Average	15.346		

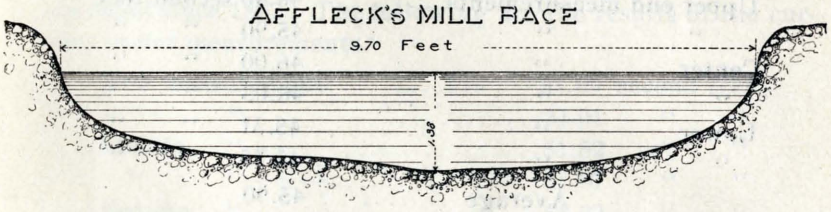

TABLE No. II.

Mean Cross Section. Station in Feet	Depth in Feet	Station in Feet	Depth in Feet	HYDRAULIC ELEMENTS	Numerical Values
0.00	edge	9.00	1.73	Slope in Feet per foot	0.000317 feet
0.25	0.50	9.66	0.00	Slope in Feet per 100 ft.	0 0317 "
1·00	0.87			Slope in Feet per mile	1.6716 "
2.00	1.10			Mean discharge	15.346 sec. ft.
3.00	1.18			Wetted perimeter	10.70 lin. ft.
4.00	1.25			Area of water section	10.687 sq. ft.
5.00	1.38			Mean velocity	1.436 lin. ft.
6.00	1.35			Hydraulic mean radius	0.998
7.00	1.33			Coefficient of roughness [n]	0.017666.
8.00	1.13			" C in $V=C\sqrt{RS}$	80.786

Experiment No. 3.

On June 23, 1897, a site for an experiment was selected on the Logan, Hyde Park and Smithfield Canal, near the mouth of Logan Canyon, Cache Co., Utah. The water was first turned into the canal in 1882, and at the time of the ex-

periment it had been operated for fifteen years. The bottom and sides were smooth and composed of earth and gravel. The particles of gravel varied in size from one-half to one inch in diameter, and in places there were pebbles from one to two inches in size. There was no vegetation, save a slight growth of grass on one side. The current meter measurements are given below.

Upper end measurements	.....	46.40	second	feet
" "	.....	45.90	"	"
Center "	.....	46.00	"	"
" "	.....	46.03	"	"
Lower "	.....	45.31	"	"
" "	.....	45.75	"	"
Average	....	45.90		

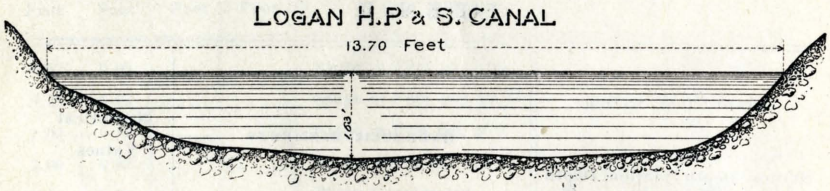

TABLE No. III.

Mean Cross Section				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	9.00	1.60	Slope in feet per foot	0.000833
0·25	0.23	10 00	1.56	Slope in feet per 100 ft	0.0833
1.00	0.56	11.00	1.50	Slope in feet per mile	4 3982
2.00	1.12	12.00	1.38	Mean discharge	45.90 sec. feet
3.00	1.38	13 00	0.72	Wetted perimeter	14.80 lin. feet
4.00	1.45	13.66	0.00	Area of water section	17.795 sq. feet
5.00	1.57	.....	.....	Mean velocity	2.579 lin. feet
6.00	1.63	....	... .	Hydraulic mean radius	1.202
7.00	1.55	.....	.... ..	oefficient of roughness [n]	0.018444
8.00	1.54	.. ..	.....	" C in $V=C\sqrt{R.S}$	81.504

Experiment No. 4.

This was made on a sixty foot section of the Logan, Hyde Park and Smithfield Canal, near its point of diversion in Logan Canyon. The channel was composed of well packed coarse gravel and small cobble rock. The common sizes were one inch, two inches and three inches in diameter in about equal proportion. There were some weeds on one edge, but it is doubtful if they retarded the flow. This canal had been operated since 1882. The following are the results of the current meter measurements.

Top measurement	.....	51.09	second feet.
" "	.....	51.01	" "
Middle "	.....	51.52	" "
" "	.....	51.07	" "
Bottom "	.....	51.92	" "
" "	.....	51.57	" "
Average	.....	51.36	

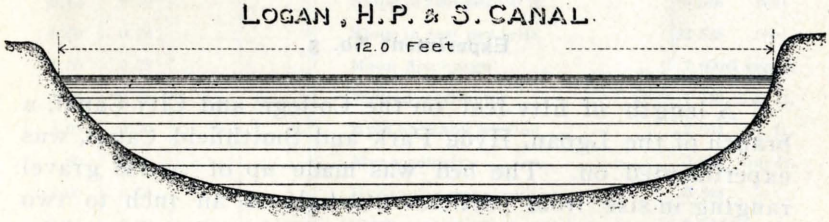

TABLE No. IV.

Mean Cross Section				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	9.00	1.93	Slope in feet per foot	0.000766 feet
0.25	0.33	10.00	1.76	Slope in feet per 100 ft	0.0766 feet
1.00	1.11	11.00	1.30	Slope in feet per mile	4.048 feet
2.00	1.63	12.00	0.00	Mean discharge	51.365 sec. feet
3 00	1.90			Wetted perimeter	13.56 lin, feet
4.00	2.03			Area of water section	20.61 sq. feet
5.00	2.08			Mean velocity	2.492 lin. feet
6 00	2.03			Hydraulic mean radius	1.519
7.00	2.02			Coefficient of roughness (n)	0.021312
8.00	2.02			" C in $V=C\sqrt{RS}$	73.053

Experiment No. 5.

A length of fifty feet on the College and City Canal, a branch of the Lgoan, Hyde Park and Smithfield Canal, was experimented on. The bed was made up of coarse gravel ranging in size from particles one-half of an inch to two inches in diameter, more or less imbedded in finer materials. The edges were somewhat irregular, with some willow roots, but there was no vegetation in the channel. The meter measurements were:

First trial	7.73	second feet
Second trial	7.54	" "
Third trial	7.48	" "
Fourth trial	7.63	" "
Average	7.60	

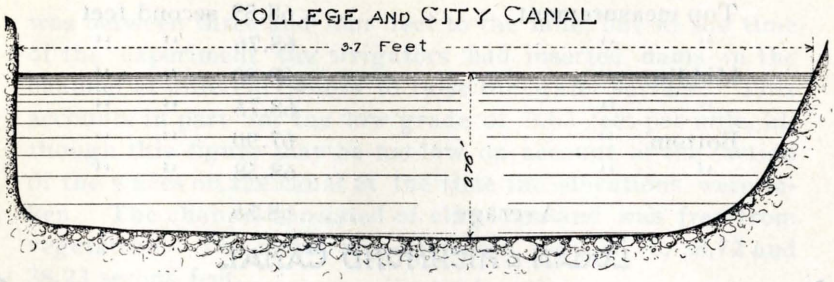

TABLE No. V.

Mean Cross Section				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	.....	....	Slope in feet per foot	0.00616 feet
0.12	0.70	....	.....	Slope in feet per 100 ft	0.616 feet
0.50	0.74	.....	.....	Slope in feet per mile	32.525 feet
1.00	0.75	.....	.....	Mean discharge.	7.60041 sec. ft,
1.50	0.75	.....	....	Wetted perimeter	4.730 lin. ft.
2.00	0.76	.....	.....	Area of water section....	2.594 sq. ft.
2.50	0.76	....	.....	Mean velocity	2.930 lin. ft.
3.00	0.74	.....	.....	Hydraulic mean radius.....	0.548
3.50	0.39	.....	.....	Coefficient of roughness (n).....	0.023824
3.70	0.00	.....	.....	" C in $V=C\sqrt{RS}$	50.43

Experiment No. 6.

Number six was made on the Logan and Richmond Canal, built in 1864-67, and is the largest canal which diverts water from the Logan river. The bottom and sides were smooth, free from vegetation and composed of clayey loam. With the exception of some indentations near the top on the sides the canal was in good condition. Meter measurements were made at three points of the 100 foot section with the following results:

Top measurement	.....	68.59	second feet
" "	.....	68.76	" "
Middle "	.....	68.80	" "
" "	.....	68.75	" "
Bottom "	.....	67.90	" "
" "	.....	68.58	" "
Average	.....	68.56	

LOGAN & RICHMOND CANAL

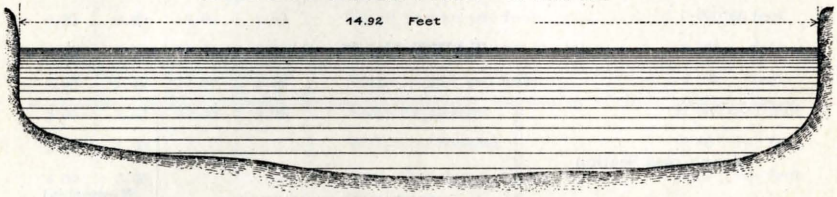

TABLE No. V

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	9.00	2.40	Slope in feet per foot	0.00046
0.25	1.40	10.00	2.33	Slope in feet per 100 ft.....	0.046
1.00	1.75	11.00	2.33	Slope in feet per mile	2.429
2.00	1.92	12.00	2.25	Mean discharge.....	68.56 sec. feet
3.00	2.02	13.00	2.18	Wetted perimeter.....	17.80 lin. feet
4.00	2.08	14.00	1.90	Area of water section	32.02 sq. feet
5.00	2.19	14.92	0.00	Mean velocity	2.141 lin. feet
6.00	2.33	.....	.....	Hydraulic mean radius	1.742
7.00	2.42	.....	.....	Coefficient of roughness (n)	0.02113
8.00	2.42	.....	.....	" C in $V=C\sqrt{RS}$	75.633

Experiment No 9.

The Walker tract canal, a continuation of the Point Lookout Canal, was built in 1892 to carry a much larger volume than that shown in Experiment No 9. The true grade

was between three and four feet to the mile, but at the time of the experiment the irrigators had inserted dams in the channel at different points to raise the water surface. This accounts in part for the low grade of 0.63 feet per mile, although this figure may be too low on account of the action of the waves on the canal at the time the elevations were taken. The channel consisted of clay loam and was free from vegetation. The meter measurements were 38.70, 38.72 and 38.23 second feet.

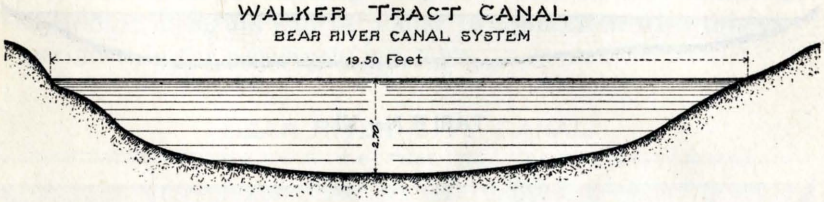

TABLE NO. IX.

Mean Cross Section.				HYDRAULIC ELEMENTS	Nnmerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	11.00	2.67	Slope in Feet per foot	0.00012 feet
0.25	0.22	12.00	2.60	Slope in Feet per 100 ft	0.012 "
1.00	0.52	13.00	2.45	Slope in Feet per mile	0.6336 "
2.00	1.40	14.00	2.30	Mean discharge	38.55 sec. feet
3.00	1 95	15.00	2.15	Wetted perimeter	20.90 lin. feet
4.00	2.27	16.00	1.88	Area of water section	38.32 sq. feet
5.00	2.35	17.00	1.45	Mean velocity	1.006 lin. feet
6.00	2.50	18.00	0.77	Hydraulic mean radius	1.833
7.00	2.66	19.00	0.22	Coefficient of roughness (n)	0.02318
8.00	2.70	19.50	0.00	" C in $V=C\sqrt{RS}$	67.831
9.00	2.70				
10.00	2.67				

Experiment No. 11.

This experiment was made at the Point Lookont Canal when the volume carried (87.29 sec. ft.) was small in comparison to the maximum capacity which is nearly 600 second feet.

The surface width was nearly 36 feet, while the depth of water at the deepest place was about 2¼ feet. The section chosen was entirely free from aquatic plants, but more or less vegetation was found both above and below the site. The channel was smooth and composed of a clay loam lined with sediment. The meter measurements were 87.64, 87.82 and 86.40 giving an average of 87.29 second feet.

POINT LOOKOUT CANAL
BEAR RIVER CANAL SYSTEM

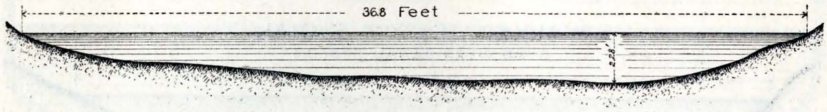

TABLE No. XI.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
				Slope in feet per foot	0.00027 feet
				Slope in feet per 100 ft	0 027 feet
				Slope in feet per mile	1.426 feet
				Mean discharge	87.287 sec. ft.
				Wetted perimeter	36 725 lin, ft.
				Area of water section	58.935 sq. ft.
				Mean velocity	1.481 lin. ft.
				Hydraulic mean radius	1.603
				Coefficient of roughness (n)	0.0218
				" C in $V=C\sqrt{RS}$	71.188

Experiment No. 12.

This experiment was made on the Bear River City Canal 900 feet below the head gates. This canal is a branch of the Bear River canal system and the conditions as regards materials, length of time in operation and coating of fine sediment were similar to those of the preceding test. This channel was likewise trapezoidal with 1 to 1 slopes when first made,

but it has since changed to the form outlined in Fig. 12. Current meter measurements were made at the top, middle and bottom of the portions tested with the results as here given.

First measurement	10.54	second feet
Second "	10.91	" "
Third "	10.58	" "
Average	10.68	" "

This average discharge together with all the remaining hydraulic elements will be found in connection with this experiment in the accompanying table.

TABLE No. XII.

Mean Cross Section				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	9.00	0.92	Slope in feet per foot	0.00012 feet
0.25	0.26	10.00	0.80	Slope in feet per 100 ft	0.012 feet
1.00	0.53	11.00	0.42	Slope in feet per mile	0.6336 feet
2.00	0.86	11.36	0.00	Mean discharge	10.679 sec. feet
3.00	0.98			Wetted perimeter	11.85 lin. feet
4.00	1.07			Area of water section	10.24 sq. feet
5.00	1.16			Mean velocity	1.042 lin. feet
6.00	1.22			Hydraulic mean radius	0.864
7.00	1.10			Coefficient of roughness (n)	0.013537
8.00	1.05			" C in $V=C\sqrt{RS}$	102.16

Experiment No. 13.

Was made on a small lateral from the Corinne Branch of the Bear River Canal. The section in outline as shown in Fig. 13 is quite good and the channel excavated in clay loam was well lined with fine sediment, but there were numerous foot prints of stock throughout the portion tested which were expected to reduce the coefficient of roughness below the .0186 given in the acompanying table. There were no weeds nor acquatic vegetation to check the flow. The current meter measurements were: 2.75, 2.45 and 2.40 second feet, or an average of 2.53 second feet.

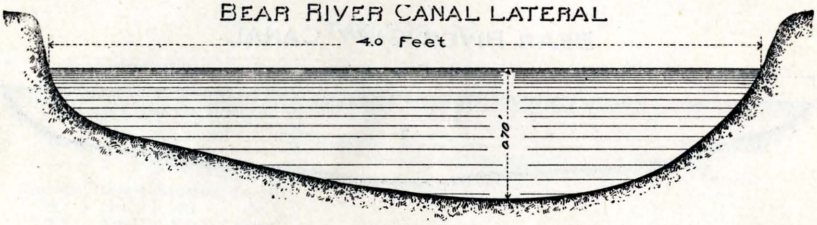

TABLE No. XIII.

Mean Cross Section				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	.....	.....	Slope in feet per foot	0.00068 feet
0.25	0.31	....	.....	Slope in feet per 100 ft	0.068 feet
1.00	0.51	.....	.....	Slope in feet per mile	3.59 feet
2.00	0.70	.....	.....	Mean discharge.	2.53 sec. ft.
3.00	0.71	.....	.....	Wetted perimeter	4.46 lin. ft.
3.75	0.33	.....	.....	Area of water section.....	2.23 sq. ft.
4.00	0.00	.....	.....	Mean velocity	1.135 lin. ft.
....	....	.....	.....	Hydraulic mean radius.....	0.500
....	....	.....	.....	Coefficient of roughness (n).....	0.019434
....	....	.....	.....	" C in $V=C\sqrt{RS}$	61.55

Experiment No. 14.

This test was made on a lateral of the Bear River Canal near the Central Farm. The formation was a clay loam, and the water channel was coated with sediment and also contained patches of what is usually termed "horse tail" moss. The presence of these plants together with somewhat uneven edges doubtless retarded the velocity. The discharge was obtained from the average of the three meter measurements which were 4.69, 4.67 and 4.54 second feet.

BEAR RIVER CANAL LATERAL

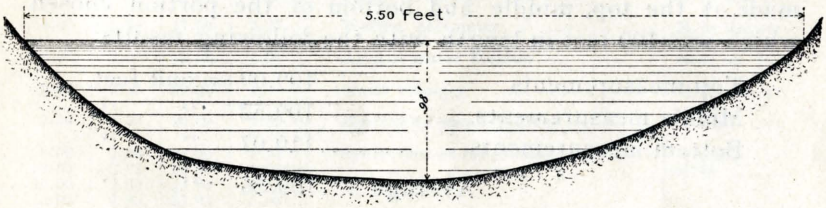

TABLE No. XIV.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00			Slope in feet per foot	0.00075 feet
0.25	0.26			Slope in feet per 100 ft	0.075 feet
1.00	0.77			Slope in feet per mile	3.96 feet
2.00	0.95			Mean discharge	4.63 sec. ft.
3.00	0.98			Wetted perimeter	6.00 lin, ft.
4.00	0.75			Area of water section	3.89 sq. ft.
5.00	0 33			Mean velocity	1.191 lin. ft.
5.46	0.00			Hydraulic mean radius	0.648
				Coefficient of roughness (n)	0.022983
				" C in $V=C\sqrt{RS}$	54.025

Experiment No. 15.

The place selected for this experiment was on the Corinne Branch of the Bear River Canal about four miles below the division gates. It had been operated six years prior to the test and although its section when new was horizontal on the bottom, with side slopes in excavation of one to one, its form in 1897 approached the segment of an ellipse as may be seen by reference to Fig. 15. This canal where the test was made was entirely free from vegetation and there was nothing to obstruct the flow except the friction on the smooth perimeter which was coated with fine silt. Meter measurements were made at the top, middle and bottom of the portion chosen which was 100 feet in length with the following results:

Top measurements	109.09	second feet.
Middle measurements	109.52	" "
Bottom measurements	110.07	" "
Average....	109.56	" "

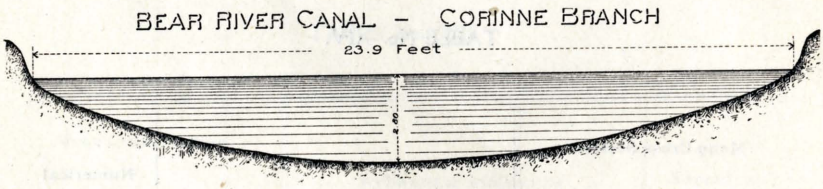

TABLE No. XV.

Mean Cross Section.				HYDRAULIC ELEMENTS	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.25	0.30	13.00	2.73	Slope in Feet per foot	0.00027 feet
1·00	0.70	14.00	2.65	Slope in Feet per 100 ft.	0 027 "
2.00	1.12	15.00	2.57	Slope in Feet per mile	1.4256 "
3.00	1.46	16.00	2.43	Mean discharge	109.56 sec. ft.
4.00	1.76	17.00	2.27	Wetted perimeter	24.98 lin. ft.
5.00	2.00	18.00	2.06	Area of water section	46.42 sq. ft.
6.00	2.23	19.00	1.77	Mean velocity	2.359 lin. ft.
7.00	2.40	20.00	1.50	Hydraulic mean radius	1.858
8.00	2.60	21.00	1.22	Coefficient of roughness [n]	0.01552.
9.00	2.72	22.00	0.93	" C in $V=C\sqrt{RS}$	105.78
10.00	2.80	23.00	0·52		
11 00	2.80	23.93	0.00		
12.00	2.79				

Experiment No. 16.

The Millville and Providence Canal is the highest diverting water from Blacksmith Fork River in Cache County, Utah. It was completed in 1864 so that at the time of the experiment, water had been flowing through it for 33 years. This canal was built in compact clay dotted with small rock fragments half an inch across. One side was perfectly smooth, while the other had a few willow roots projecting into the water. With this exception and the presence of a few small cobble rock in the bed the conditions were all favorable. The results of three meter measurements in a 50 foot length were:

Top measurement	22.06	second feet.
Middle "	22.27	" "
Bottom "	22.51	" "
Average	22.28	

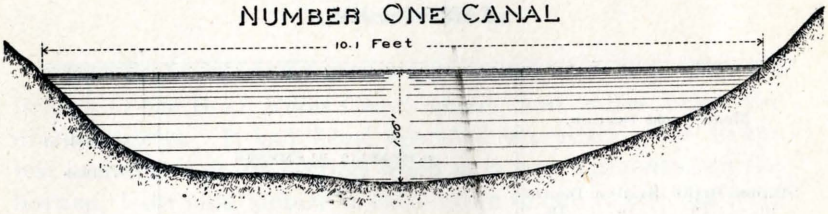

TABLE No. XVI.

Mean Cross Section				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	9.00	0.68	Slope in feet per foot	0.00062
0·25	0.25	10 00	0.10	Slope in feet per 100 ft	0.062
1.00	0.92	11.06	0.00	Slope in feet per mile	3 2736
2.00	1.35	.....	.....	Mean discharge	22.278 sec. feet
3.00	1.42	.....	.....	Wetted perimeter	10.80 lin. feet
4.00	1.47	.....	.....	Area of water section	11.50 sq. feet
5.00	1.56	.....	.....	Mean velocity	1 .937 lin. feet
6.00	1.49	....	.....	Hydraulic mean radius	1.065
7.00	1.37	.....	.....	Coefficient of roughness [n]	0.01946
8.00	1.05	.....	.....	" C in $V=C\sqrt{RS}$	74.634

Experiment No 17.

On August 28, 1897, an experiment was made on the Logan and Hyde Park Canal, which flows through Logan City, Utah. An even stretch of 75 feet was chosen within the city limits and the discharges at the top, middle and bottom of this section obtained by a current meter were: 23.95, 23.67 and 23.04 second feet respectively.

This canal, as the sketch in Fig. 17 shows, was over 14 feet wide on top and only about two feet deep with a mean velocity of 1.08 feet per second. The bed was clay covered with a thin layer of fine sand and about one-sixth of the perimeter was covered with a low creeping water plant.

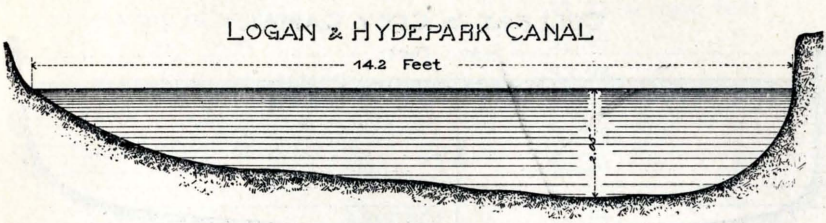

TABLE No. XVII.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	9.00	1.93	Slope in feet per foot	0.000146 ft.
0.25	0.22	10.00	2.05	Slope in feet per 100 ft	0.0146 "
1.00	0.63	11.00	2.00	Slope in feet per mile	0.7709 "
2.00	1.07	12.00	1.98	Mean discharge	23.554 sec. ft.
3.00	1.38	13.00	1.64	Wetted perimeter	15.60 lin. feet
4.00	1.53	13.75	0.90	Area of water section	21.78 sq. feet
5.00	1.56	14.66	0.00	Mean velocity	1.081 lin. feet
6.00	1.71	.....	.....	Hydraulic mean radius	1.396
7.00	1.73	....	....	Coefficient of roughness (n)	0.019729
8.00	1.87	.....	.....	" C in $V=C\sqrt{RS}$	75.719

Experiment No. 18.

This experiment was also made on the College and City canal. There was no vegetation to check the velocity but the sides were uneven and the bed was covered with fragments of disintegrated flat rock, ranging in size from one-half to two inches across the greatest dimension. The meter measurements were 5.69, 5.67 and 5.61 second feet.

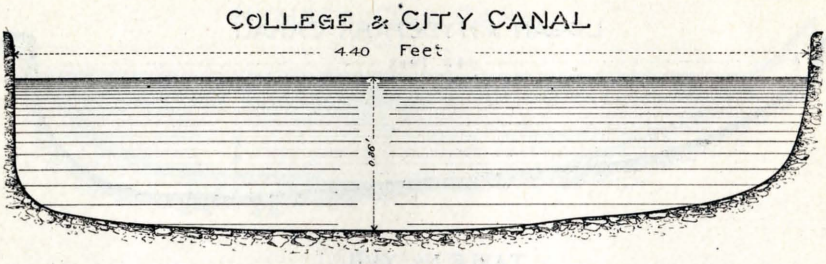

TABLE NO. XVIII.

Mean Cross Section.				HYDRAULIC ELEMENTS	Nnmerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	....		Slope in Feet per foot	0.0016 feet
0.25	0.75	....	....	Slope in Feet per 100 ft	0.160 "
1.00	0.84	....	....	Slope in Feet per mile	8.448 "
2.00	0.86	....	....	Mean discharge	5.659 sec. feet
3.00	0.82	....	....	Wetted perimeter	5.44 lin. feet
4.00	0.67	....	....	Area of water section	3.51 sq. feet
4.43	0.00	....	....	Mean velocity	1.612 lin. feet
....	....	....	.	Hydraulic mean radius	0.645
....	....	....	....	Coefficient of roughness (n)	0.024654
....	....	....	....	" C in $V=C\sqrt{RS}$	50.179

Experiment No. 19.

The Lewiston Canal begun in 1860 and completed in 1880 diverts water from Cnb River and waters the bench lands near Franklin, Idaho and Lewiston, Utah. It is capable of conveying about 125 second feet of water when running full but at the time of the experiment it contained but 32.72 second feet.

The channel consisted of smooth light colored clay, but about one-fifth of the perimeter was covered with a growth of fibrous moss locally called "frog moss." The meter measurements were:

At top of section	33.22	second feet
" " "	32.92	" "
At middle of section	32.94	" "
" " "	32.54	" "
At bottom of section	32.33	" "
" " "	32.39	" "
Average	32.72	" "

LEWISTON CANAL

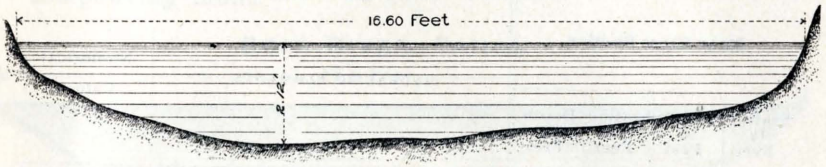

TABLE NO. XIX.

Mean Cross Section.				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	9.00	2.01	Slope in Feet per foot	0.0002 feet
0.25	0.40	10.00	1.87	Slope in Feet per 100 ft	0.020 "
1.00	0.91	11.00	1.80	Slope in Feet per mile	1.056 "
2.00	1.40	12.00	1.80	Mean discharge	32.723 sec. feet
3.00	1.72	13.00	1.65	Wetted perimeter	18.075 lin. feet
4.00	1.98	14.00	1.50	Area of water section	27.53 sq. feet
5.00	2.12	15.00	1.37	Mean velocity	1.188 lin. feet
6.00	2.12	16.00	0.90	Hydraulic mean radius	1.523
7.00	2.05	16.63	0.00	Coefficient of roughness (n)	0.022351
8.00	2.01	....	....	" C in $V=C\sqrt{RS}$	68.07

Experiment No. 20.

On this test the discharge was obtained by a trapezoidal weir and the channel was composed of small pebbles imbedded in sand. Solveson and his neighbors own the ditch, which diverts water from the Blacksmith Fork River and waters the low land in the river bottom.

TABLE No. XX.

Mean Cross Section				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	.... ..	...	Slope in feet per foot	0.00056 feet
0.25	0.07	.... ..	... ...	Slope in feet per 100 ft	0.056 feet
1.00	0.34	....	.... ..	Slope in feet per mile....	2.957 feet
2.00	0.54	.....	.....	Mean discharge.	4.034 sec. feet
3 00	0.72	....	.. ....	Wetted perimeter	7.73 lin. feet
4.00	0.83	.... ..	.....	Area of water section.....	4.00 sq. feet
5.00	0.74	...	.....	Mean velocity	1.008 lin. feet
6 00	0.50	. ....	.....	Hydraulic mean radius.....	0.5173
7.00	0.28	... ..	... ...	Coefficient of roughness (n)	0.020141
7.55	0.00	.... ..	.....	" C in $V=C\sqrt{RS}$	59.224

Experiment No. 21.

Experiment No. 21 was made on the main line of the Bear River Canal about seven miles from the dam and 200 feet above the Corinne Division Gates. Water was first turned into this portion of the system by the writer in the spring of 1891, and during the six years of operation the action of the water had changed the section from a trapezoidal form having a bottom width of about 15 feet and side slopes of one to one, to that of the segment of an ellipse as shown in Fig. 21. The formation is a clayey loam and the channel when measured was covered with a coating of sediment. It was entirely free from vegetation, gravel or pebbles, of regular cross section and in excellent condition.

Three meter measurements were made with the following results:

First measurement	226.56	second	feet
Second "	224.94	"	"
Third "	225.14	"	"
Average	225.55	"	"

The results of this experiment are given in the accompanying table.

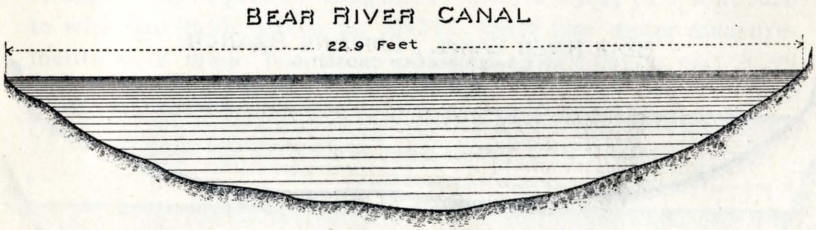

TABLE No. XXI.

Mean Cross Section.				HYDRAULIC ELEMENTS	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.25	0.30	18.00	2.75	Slope in Feet per foot	0.00031 feet
1.00	0.68	19.00	2.45	Slope in Feet per 100 ft.	0 031 "
3.00	1.98	20.00	2.00	Slope in Feet per mile	1.637 "
5.00	2.90	21.00	1.85	Mean discharge	225.55 sec. ft.
7.00	3.26	22.00	0.73	Wetted perimeter	25.00 lin. ft.
9.00	3.66	22.86	0 00	Area of water section	62.30 sq. ft.
11.00	3.84			Mean velocity	3.62 lin. ft.
13.00	3.94			Hydraulic mean radius	2.49
15.00	3.60			Coefficient of roughness [n]	0.0133686.
17.00	3.10			" C in $V=C\sqrt{RS}$	130.24

Experiment No. 22.

This test was made on the same canal ten miles below the place of the last test at a point about 1300 feet below the

Lower Malad Crossing. The date of the experiment was September 9, 1897, which accounts for the small volume in the canal, the irrigation season in that section being nearly past. This canal was similar to those previously described and was in excellent condition at the time of the experiment. The formation was a clayey loam and the action of the water for six summers had left its channel quite smooth and well coated with silt. The discharge was obtained by meter measurements in the usual manner.

TABLE No. XXII.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	9.00	2.05	Slope in feet per foot	0.000273 ft.
0.25	0.24	10.00	2.03	Slope in feet per 100 ft	0.0273 "
1.00	0.75	11.00	2.05	Slope in feet per mile	1.4414 "
2.00	1.32	12.00	2.08	Mean discharge	64.024 sec. ft.
3.00	1.72	13.00	2.06	Wetted perimeter	19.775 lin. feet
4.00	1.94	14.00	1.98	Area of water section	31.655 sq. feet
5.00	2.00	15.00	1.74	Mean velocity	2.022 lin. feet
6.00	2.16	16.00	1.37	Hydraulic mean radius	1.60
7.00	2.24	17.00	0.97	Coefficient of roughness (n)	0.016447
8.00	2.13	18.00 18.87	0.69 0.00	" C in $V=C\sqrt{RS}$	96.747

Experiment No. 24.

This experiment was made on a large, well formed canal, the property of the Brigham City Electric Light Company, and located near the mouth of Box Elder Canyon in the county of the same name. The bed consisted of medium sized gravel unpacked, and about one-third of the water area was filled with long waiving water plants resembling horse tails. The presence of these plants retarded the velocity and no doubt changed the degree of roughness from a value of about .020 to what the table gives as .0424. Only two meter measurements were made but these checked very closely; viz: 30.99 and 31.16 second feet.

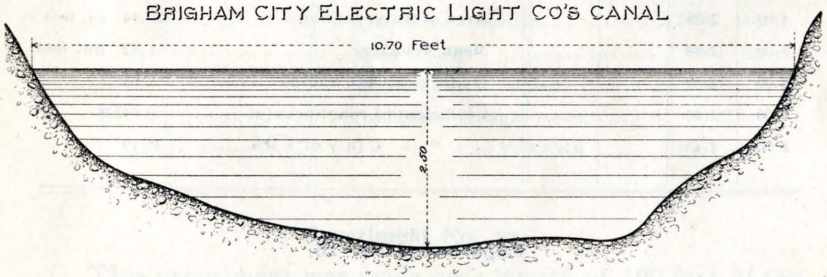

TABLE No. XXIV.

Mean Cross Section				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	9.00	1.72	Slope in feet per foot	0.00115
0·25	0.43	10.00	1.10	Slope in feet per 100 ft	0.115
1.00	1.30	10.70	0.00	Slope in feet per mile	6 072
2.00	1.71			Mean discharge	31.073 sec. feet
3.00	2 08			Wetted perimeter	12.60 lin. feet
4.00	2.28			Area of water section	20.44 sq. feet
5.00	2.48			Mean velocity	1.52 lin. feet
6.00	2.50			Hydraulic mean radius	1.62
7.00	2.40			Coefficient of roughness [n]	0.04238
8.00	2.43			" C in $V=C\sqrt{RS}$	35.19

Experiment No 26.

In this experiment the flow was much impeded by horse tail moss which covered about three-fourths of the water section. The bed was composed of medium sized gravel and the discharge was obtained by a meter.

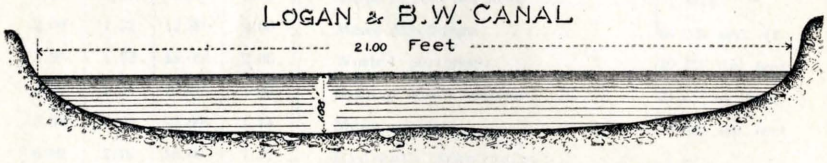

TABLE No. XXVI.

Mean Cross Section				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
....	....	....	....	Slope in feet per foot	0.00033 feet
....	....	....	....	Slope in feet per 100 ft	0.033 feet
....	....	....	....	Slope in feet per mile	1.74 feet
....	....	....	....	Mean discharge	24.58 sec. ft,
....	....	....	....	Wetted perimeter	22.00 lin. ft.
....	....	....	....	Area of water section	29.14 sq. ft.
....	....	....	....	Mean velocity	0.843 lin. ft.
....	....	....	....	Hydraulic mean radius	1.324
....	....	....	....	Coefficient of roughness (n)	0.03523
....	....	....	....	" C in $V=C\sqrt{RS}$	40.33

Experiment No. 27.

This experiment was made on a length of 100 feet of the Logan, Hyde Park and Thatcher canal near Logan City, Utah. The sides of the channel were smooth and coated with sediment, the bottom consisted of earth, gravel and pebbles, some of which were 2½ inches in diameter. The coarser material covered about one-fourth of the perimeter.

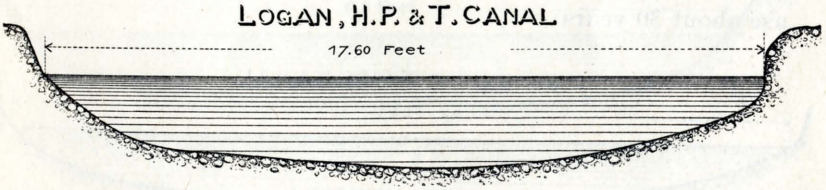

TABLE No. XXVII.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
				Slope in feet per foot	0.0006 feet
				Slope in feet per 100 ft	0.06 feet
				Slope in feet per mile	3.168 feet
				Mean discharge	60.23 sec. ft.
				Wetted perimeter	18.90 lin. ft.
				Area of water section	30 60 sq. ft.
				Mean velocity	1.97 lin. ft.
				Hydraulic mean radius	1.618
				Coefficient of roughness (n)	0.02464
				" C in $V=C\sqrt{RS}$	63.16

Experiment No. 29.

The Providence Town canal, or ditch, was only part full when measured by weir on September 16, 1897. The length of the weir was two feet and the depth of the water 0.376 feet. The bed was composed of well packed and smooth gravel about the size of Spanish nuts, imbedded in sand and sediment. There was no vegetation and the ditch had been in use about 30 years.

TABLE No. XXIX.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
				Slope in feet per foot	0.0004 feet
				Slope in feet per 100 ft	0.04 feet
				Slope in feet per mile	2.112 feet
				Mean discharge	1.553 sec. ft.
				Wetted perimeter	6.34 lin. ft.
				Area of water section	2.55 sq. ft.
				Mean velocity	0.609 lin. ft.
				Hydraulic mean radius	0.462
				Coefficient of roughness (n)	0.02227
				" C in $V=C\sqrt{RS}$	47.998

Experiment No. 31.

This experiment was made in the Providence Upper canal near the town of Providence, Utah. The conditions were similar to those of No. 29 and the flow was measured over a weir two feet in length and having 0.494 feet flowing over the crest.

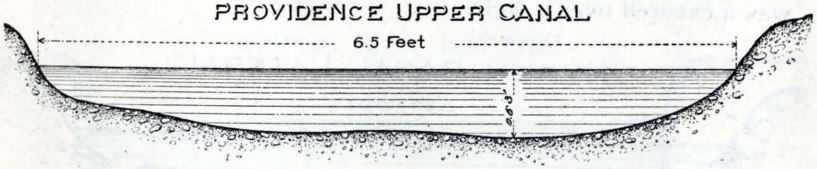

TABLE NO. XXXI.

Mean Cross Section.				HYDRAULIC ELEMENTS	Nnmerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	.....	.....	Slope in Feet per foot.....	0.00043 feet
0.25	0.27	.....	.....	Slope in Feet per 100 ft.....	0.043 "
1.00	0.33	.....	.....	Slope in Feet per mile	2 270 "
2.00	0.58	.....	.....	Mean discharge.....	2.338 sec. feet
3.00	0.58	.....	.....	Wetted perimeter	6.80 lin. feet
4.00	0.62	.....	.....	Area of water section	3.287 sq. feet
5.00	0.63	.....	.....	Mean velocity.....	0.7113 lin. feet
6.00	0.40	.....	.....	Hydraulic mean radius	0.483
6.53	0.00	.....	.....	Coefficient of roughness (n)	0.02285
.....	.....	.....	.....	" C in $V=C\sqrt{RS}$	49.34

Experiment No. 33.

This is an instance in which a small volume of water flowed very slowly over a rough surface, notwithstanding the fall was 64 feet to the mile. This experiment was made on a lateral of the Hyrum canal, near the town of Hyrum, Cache County. The channel consisted chiefly of cobble rock ranging in size from one to three inches in diameter. The flow was measured over a weir.

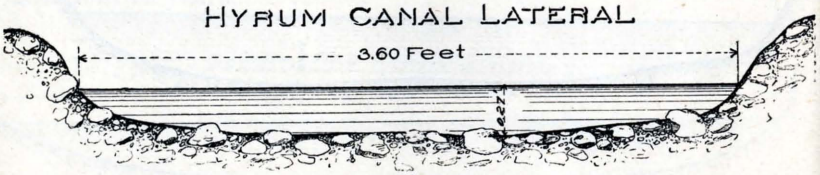

TABLE No. XXXIII.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	....	..	Slope in feet per foot	0.01212 ft.
0.125	0.12	....	....	Slope in feet per 100 ft	1.212 "
0.50	0.20	..	...	Slope in feet per mile	63.99 "
1.00	0.26	....	..	Mean discharge.....	0.807 sec. ft.
1.50	0.25	....	....	Wetted perimeter	4.00 lin. feet
2.00	0 27	....	..	Area of water section	0.795 sq. feet
2.50	0.26	....	....	Mean velocity	1.015 lin. feet
3.00	0.22	....	...	Hydraulic mean radius	0.1987
3.50	0.10	....	.. .	Coefficient of roughness (n)	0.03648
3.60	0.00		.	" C in $V=C\sqrt{RS}$	20.68

Experiment No. 35.

This experiment was made on a small stream which supplies the Temple grounds in Logan, Utah. The natural channel was made up of sand and silt, but at the time the experiment was made it was more than one-third full of horse tail moss. The discharge was obtained by building a weir.

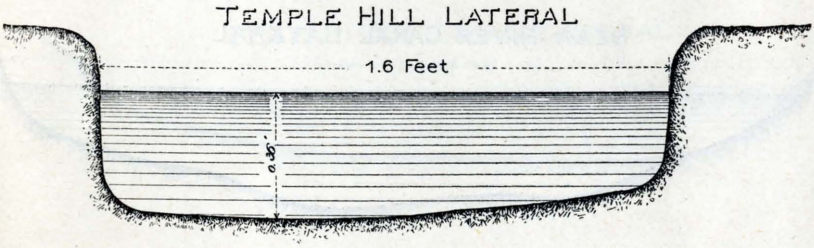

TABLE No. XXXV.

Mean Cross Section				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0.00	0.00	.... ..	...	Slope in feet per foot	0.00442 feet
0.125	0.34	....	... ..	Slope in feet per 100 ft	0.442 feet
0.50	0.36	.. ...	.... ..	Slope in feet per mile	23.338 feet
1.00	0.33	.....	.....	Mean discharge	0.283 sec. feet
1.50	0.27	.... ..	.. ....	Wetted perimeter	2.10 lin. feet
1.60	0.00	.... ..	.....	Area of water section.....	0.52 sq. feet
..	....	...	.....	Mean velocity	0.54 lin. feet
....	....	.. ...	.... .	Hydraulic mean radius..... ...	0.25
...	..	... ..	... ..	Coefficient of roughness (n)	0.046911
...	...	... .	.. ....	" C in $V=C\sqrt{RS}$	16.276

Experiment No. 37.

This experiment was made on one of the Central Farm laterals. The bed was composed of clay but the cross-section was not uniform and there were a few bunches of grass scattered along the edges. The discharge was measured over a weir.

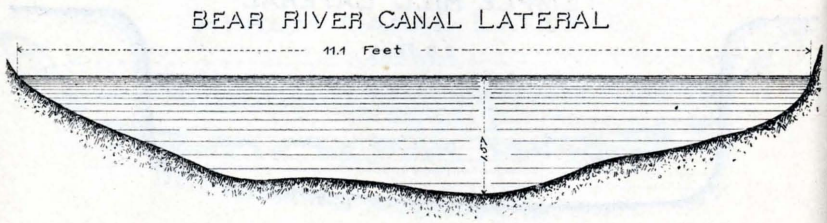

TABLE NO. XXXVII.

Mean Cross Section				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
0·25	0.25	10.00	0.80	Slope in feet per foot	0.00017
1.00	0.62	11.00	0.32	Slope in feet per 100 ft	0.017
2.00	1.05	10.10	0.00	Slope in feet per mile	0 898
3.00	1.46			Mean discharge	7.83 sec. feet
4.00	1.45			Wetted perimeter	11.80 lin. feet
5.00	1.54			Area of water section	12.79 sq. feet
6.00	1.64			Mean velocity	0.612 lin. feet
7.00	1.57			Hydraulic mean radius	0.084
8.00	1.27			Coefficient of roughness [n]	0.02954
9.00	1.08			" C in $V=C\sqrt{RS}$	45.08

Experiment No 38.

This test was made on a lateral of the Bear River canal in that part of the valley known as Rowville, Utah. This lateral was in good condition and lined with the same clayey sediment referred to in previous descriptions. The discharge was obtained by means of a trapezoidal weir whose bottom length was 3.15 feet and the depth of water on the crest was 0.822 feet. The cross section is shown in Fig. 38.

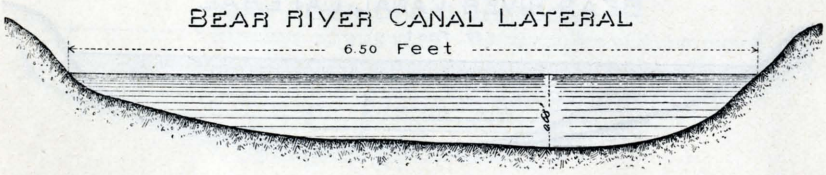

TABLE No. XXXVIII.

Mean Cross Section.				HYDRAULIC ELEMENTS	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00			Slope in Feet per foot	0.00188 feet
0.25	0.20			Slope in Feet per 100 ft.	0.188 "
1.00	0.39			Slope in Feet per mile	9.926 "
2.00	0.57			Mean discharge	7.90 sec. ft.
3.00	0.61			Wetted perimeter	6.70 lin. ft.
4.00	0.67			Area of water section	3.40 sq. ft.
5.00	0.68			Mean velocity	2.328 lin. ft.
6.00	0.40			Hydraulic mean radius	0.506
6.46	0.00			Coefficient of roughness [n]	0.013712
				" C in $V=C\sqrt{RS}$	95.27

Experiment No. 39.

A portion 80 feet in length of Central Farm lateral No. 2 was taken in this instance. The conditions were similar to No. 14 except that there was no moss in the bed but a few bunches of grass were scattered along the edges. Clay and sediment formed the bottom. The discharge was measured over a weir.

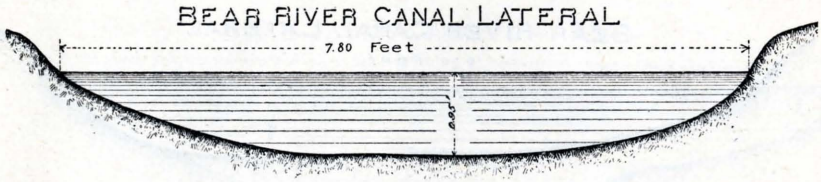

TABLE No. XXXIX.

Mean Cross Section				HYDRAULIC ELEMENTS	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	.....	.... ..	Slope in feet per foot	0.000875 feet
0.25	0 18	....	.....	Slope in feet per 100 ft	0.0875 feet
1.00	0.45	.....	.....	Slope in feet per mile	4.62 feet
2.00	0.80	.....	.....	Mean discharge	7.904 sec. ft,
3.00	0.94	.....	.. .. ..	Wetted perimeter	8.12 lin. ft.
4.00	0.95	.....	.....	Area of water section	5.738 sq. ft.
5.00	0.95	....	.....	Mean velocity	1.377 lin. ft.
6.00	0.84	..... .	.....	Hydraulic mean radius.....	0.707
7.00	0.57	.....	.....	Coefficient of roughness (n).....	0.02304
7.76	0.00	.....	.....	" C in $V=C\sqrt{RS}$	55 38

Experiment No. 42.

This experiment was made on a Central Farm lateral of the Bear River canal. The discharge was measured over a weir. The bed was composed of clay but the cross section was not uniform and there were a few bunches of grass scatterd along the edges.

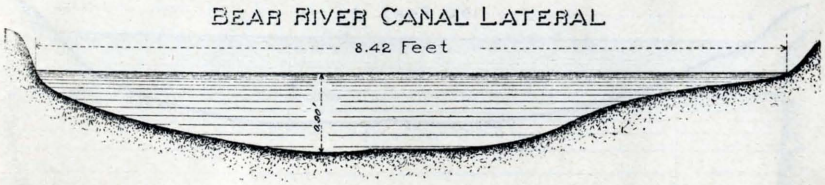

TABLE NO. XLII.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	8.42	0.00	Slope in feet per foot	0.00329 feet
0.25	0.25			Slope in feet per 100 feet	0 329 feet
1.00	0.52			Slope in feet per mile	17.39 feet
2.00	0.72			Mean discharge	8.08 sec. ft.
3.00	0.90			Wetted perimeter	8.56 lin. ft.
4.00	0.85			Area of water section	4.79 sq. ft
5.00	0.82			Mean velocity	1.685 lin. ft.
6.00	0.55			Hydraulic mean radius	0.56
7.00	0.22			Coefficient of roughness (n)	0.02925
8.00	0.096			" C in $V=C\sqrt{RS}$	39.24

Experiment No. 46.

This was made on Brigham City canal which was more than half filled with horse tail moss. The edges were also overgrown with water cress and weeds, but the part of the bottom which was exposed was covered with fine gravel.

TABLE No. XLVI.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
				Slope in feet per foot	0.00028 feet
				Slope in feet per 100 ft	0.028 feet
				Slope in feet per mile	1.478 feet
				Mean discharge	23.40 sec. ft
				Wetted perimeter	20.50 lin. ft.
				Area of water section	35.76 sq. ft.
				Mean velocity	0.654 lin. ft.
				Hydraulic mean radius	1.744
				Coefficient of roughness (n)	0.04993
				" C in $V=C\sqrt{RS}$	29.60

Experiment No. 47.

This small lateral was measured on one of the streets of Smithfield, Cache County, Utah. The channel was composed wholly of loose, coarse gravel from the size of a pea to the size of a small hen's egg. The discharge was measured over a weir.

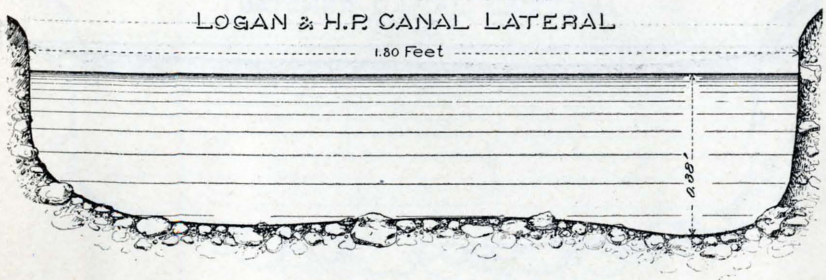

TABLE No. XLVII.

Mean Cross Section				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	.....	....	Slope in feet per foot	0.00991 feet
0.12	0.30	.... ..	... ...	Slope in feet per 100 ft	0.991 feet
0.50	0.36	....	.....	Slope in feet per mile....	52.32 feet
1.00	0.34	.....	.....	Mean discharge..	0.85 sec. feet
1.50	0.38	.....	.....	Wetted perimeter	2.32 lin. feet
1.80	0.00	.....	.....	Area of water section.....	0.63 sq. feet
....	....	...	.....	Mean velocity	1.345 lin. feet
....	....	... .	.....	Hydraulic mean radius.....	0.273
....	...	.....	.....	Coefficient of roughness (n)	0.03366
....	...	....	.....	" C in $V=C\sqrt{RS}$	25.87

Experiment No. 48.

This test was made on a lateral of Logan City canal. There was no aquatic vegitation, the bottom and sides were smooth and composed of gravel about the size of peas imbedded in finer material. The discharge was found by weir measurement.

TABLE NO. XLVIII.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	8.42	0.00	Slope in feet per foot	0.00135 feet
0.25	0.08			Slope in feet per 100 feet	0.135 feet
1.00	0.16			Slope in feet per mile	7.143 feet
2.00	0.18			Mean discharge	0.56 sec. ft.
3.00	0.18			Wetted perimeter	7.19 lin. ft.
4.00	0.14			Area of water section	1.03 sq. ft
5.00	0.16			Mean velocity	0.54 lin. ft.
6.00	0.12			Hydraulic mean radius	0.14
7.00	0.07			Coefficient of roughness (n)	0.02043
7.18	0.00			" C in $V=C\sqrt{RS}$	39.29

Experiment No 51.

This was made on a small lateral of the Thatcher Canal. There was a narrow board on each edge as shown by the sketch and the bottom was coarse gravel and cobble rock ranging in size from large peas to goose eggs. The discharge was determined by a weir.

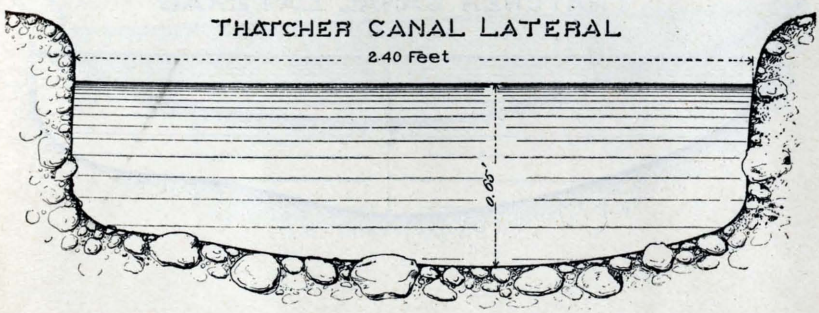

TABLE NO. LI.

Mean Cross Section				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	.....	.....	Slope in feet per foot.....	0.001125
0.12	0.52	.....	.....	Slope in feet per 100 ft.....	0.1125
0.50	0.57	.....	.....	Slope in feet per mile.....	5 94
1.00	0.62	.....	.....	Mean discharge.....	1.078 sec. feet
1.50	0 65	.....	.....	Wetted perimeter	3.25 lin. feet
2.00	0.60	.....	.....	Area of water section.....	1.44 sq. feet
2 40	0.00	.....	.....	Mean velocity	0.75 lin. feet
.....	.....	.....	.....	Hydraulic mean radius	0.44
.....	.....	.....	.....	Coefficient of roughness [n].....	0.031047
.....	.....	.....	.....	" C in $V=C\sqrt{RS}$.....	33.51

Experiment No. 52.

This test was made on another small lateral of the Thatcher canal. The bed was composed of fine silt but about three-fourths of the entire channel was covered and filled with aquatic plants of a variety similar to that described in preceding experiments.

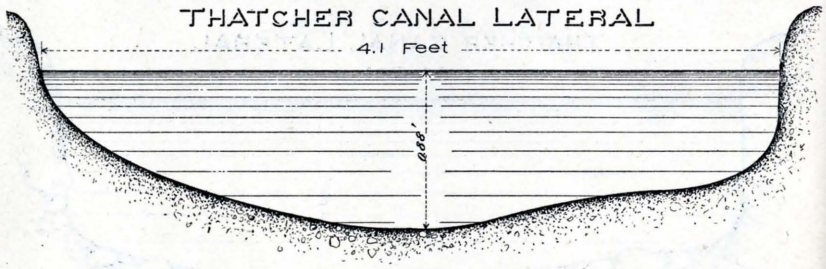

TABLE NO. LII.

Mean Cross Section.				HYDRAULIC ELEMENTS	Nnmerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	4.13	0.00	Slope in Feet per foot	0.00064 feet
0.12	0.26	.....	....	Slope in Feet per 100 ft	0.064 "
0.50	0.52	.....	.....	Slope in Feet per mile	3.379 "
1.00	0.67	.....	.. ..	Mean discharge	1.078 sec. feet
1.50	0.70	. ....	.....	Wetted perimeter	4.98 lin. feet
2.00	0.82	.....	.....	Area of water section	2.90 sq. feet
2.50	0.89	... ..	.....	Mean velocity	0.37 lin. feet
3.00	0.83	.....	.....	Hydraulic mean radius	0.583
3.50	0.73	.....	.....	Coefficient of roughness (n)	0.05291
4.00	0.68	.....	.....	" C in $V=C\sqrt{RS}$	19.16

Experiment No. 53.

About two-thirds of this small lateral was more or less covered or filled with horse tail moss, an aquatic plant which grows five or more feet in length. The remainder of the exposed surface of the bed was sediment.

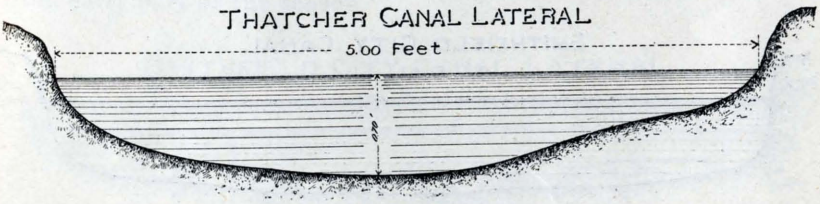

TABLE No. LIII.

Mean Cross Section				HYDRAULIC ELEMENTS	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	4.50	0.28	Slope in feet per foot	0.00107 feet
0.12	0 21	4.95	0.00	Slope in feet per 100 ft	0.107 feet
0.50	0.46			Slope in feet per mile	5.65 feet
1.00	0.60			Mean discharge	1.078 sec. ft,
1.50	0.65			Wetted perimeter	5.30 lin. ft.
2.00	0.70			Area of water section	2.57 sq. ft.
2.50	0.70			Mean velocity	0.42 lin. ft.
3.00	0.65			Hydraulic mean radius	0.48
3.50	0.51			Coefficient of roughness (n)	0.05188
4.00	0.37			" C in $V=C\sqrt{RS}$	18 41

Experiment No. 55.

This experiment was made on a Smithfield canal lateral in Cache County, Utah. The bed consisted of cobble rock partially covered with silt. The feet of cattle had made the edges irregular. The discharge was measured over a weir.

TABLE No. LV.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	4.50	0.55	Slope in feet per foot	0.00035 ft.
0.12	0.45	5.00	0.30	Slope in feet per 100 ft.....	0.035 "
0.50	0.55	5.10	0.00	Slope in feet per mile	1.86 "
1.00	0.60	....	..	Mean discharge.....	1.29 sec. ft.
1.50	0.63	....	....	Wetted perimeter.....	5.70 lin. feet
2.00	0 65	....	..	Area of water section	2.967 sq. feet
2.50	0.67	....	....	Mean velocity	0.43 lin. feet
3.00	0.64	....	....	Hydraulic mean radius	0.52
3.50	0.64	....	.. .	Coefficient of roughness (n)	0.0328
3.60	0.57		..	" C in $V=C\sqrt{RS}$	32.08

Experiment No. 56.

The conditions were similar to those of No. 57. The edges of the lateral were rough and uneven and the bed a mass of pebbles and cobble rock washed clean by the large flow in the early part of the season.

TABLE No. LVI.

Mean Cross Section.				HYDRAULIC ELEMENTS	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	4.50	0.17	Slope in Feet per foot	0.017 feet
0.12	0.14	4.60	0.00	Slope in Feet per 100 ft.	1.70 "
0.50	0.17			Slope in Feet per mile	89.76 "
1.00	0.26			Mean discharge	1.17 sec. ft.
1.50	0.28			Wetted perimeter	4.70 lin. ft.
2.00	0.28			Area of water section	1.06 sq. ft.
2.50	0.28			Mean velocity	1.10 lin. ft.
3.00	0.28			Hydraulic mean radius	0.23
3.50	0.22			Coefficient of roughness [n]	0.042
4.00	0.17			" C in $V=C\sqrt{RS}$	17.93

Experiment No. 57.

This was made on a small lateral of the Smithfield canal, which has a steep grade and a rough channel made up principally of coarse gravel and cobble rock. The flow was measured over a weir.

TABLE NO. LVII.

Mean Cross Section				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	4.50	0.18	Slope in feet per foot	0.01713
0.12	0.15	4.60	0.20	Slope in feet per 100 ft	1.713
0.50	0.18			Slope in feet per mile	90.45
1.00	0.27			Mean discharge	1.48 sec. feet
1.50	0.29			Wetted perimeter	4.75 lin. feet
2.00	0.29			Area of water section	1.11 sq. feet
2.50	0.29			Mean velocity	1.33 lin. feet
3.00	0.29			Hydraulic mean radius	0.234
3.50	0.23			Coefficient of roughness [n]	0.03774
4.00	0.18			" C in $V=C\sqrt{RS}$	21.07

Experiment No. 62.

At the time of the test this small lateral of the Hyrum Canal was partially overgrown with alfalfa and there was a strip of moss on each side which covered about one-fifth of the channel which was made up of flat fragments of rock from one to three inches across the longest diameters. A weir was used to determine the discharge.

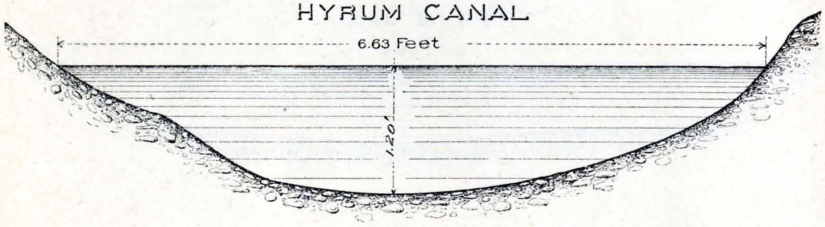

TABLE NO. LXII.

Mean Cross Section.				HYDRAULIC ELEMENTS	Numerical Values.
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	.....	.....	Slope in Feet per foot.....	0.00029 feet
0.25	0.15	.....	.....	Slope in Feet per 100 ft.....	0.029 "
1.00	0.51	.....	.....	Slope in Feet per mile	1.53 "
2.00	1.08	.....	.....	Mean discharge.....	2.47 sec. feet
3.00	1.20	.....	.....	Wetted perimeter	7.20 lin. feet
4.00	1.16	.....	.....	Area of water section	5.55 sq. feet
5.00	0.93	.....	.....	Mean velocity.....	0.44 lin. feet
6.00	0.53	.....	.....	Hydraulic mean radius	0.77
6.63	0.00	.....	.....	Coefficient of roughness (n)	0.03927
.....	.....	.....	.....	" C in $V=C\sqrt{RS}$	29.62

Experiment No. 63.

The discharge of this small ditch known as the Hyrum Canal was measured over a weir. The sides of the channel were earth but about one-half of the perimeter along the bottom was covered with rock fragments about one-half to one inch across. Weeds and alfalfa grew up to the edge of the water.

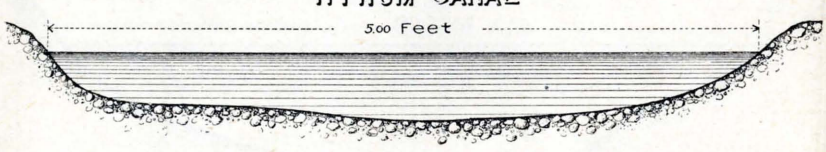

TABLE No. LXIII.

Mean Cross Section.				HYDRAULIC ELEMENTS.	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00	.....	.....	Slope in feet per foot	0.0013 feet
0.25	0.25	.....	.....	Slope in feet per 100 ft	0.13 feet
1.00	0.36	.....	.....	Slope in feet per mile	6.86 feet
2.00	0.44	.....	.....	Mean discharge	1.57 sec. ft.
3.00	0.48	.....	.....	Wetted perimeter	5.28 lin. ft.
4.00	0.40	.....	.....	Area of water section	1.87 sq. ft.
5.00	0.13	.....	.....	Mean velocity	0.84 lin. ft.
5.03	0.00	.....	.....	Hydraulic mean radius	0.35
.....	.....	.....	.....	Coefficient of roughness (n)	0.02601
.....	.....	.....	.....	" C in $V=C\sqrt{RS}$	38.92

Experiment No. 64.

The Hyrum Canal at the time this experiment was conducted only carried a large irrigation stream. The flow was measured over a weir The sides were considerably overgrown with alfalfa and weeds and its bed consisted of rock fragments from the size of hazel nuts to walnuts.

TABLE No. LXIV.

Mean Cross Section.				HYDRAULIC ELEMENTS	Numerical Values
Station in Feet	Depth in Feet	Station in Feet	Depth in Feet		
edge	0.00			Slope in Feet per foot	0.0014 feet
0.25	0.20			Slope in Feet per 100 ft.	0.14 "
1.00	0.54			Slope in Feet per mile	7.39 "
2.00	0.60			Mean discharge	2.47 sec. ft.
3.00	0.61			Wetted perimeter	5.79 lin. ft.
4.00	0.59			Area of water section	2.82 sq. ft.
5.00	0.38			Mean velocity	0.88 lin. ft.
5.50	0.00			Hydraulic mean radius	0.49
				Coefficient of roughness [n]	0.03187
				" C in $V=C\sqrt{RS}$	33.55

The writer presents the results of the experiments just described in the hope that they may aid those who build and operate the irrigation systems of the West to arrive at a better understanding regarding the behavior and carrying capacities of irrigation canals. In planning new systems it is necessary to know, before the ditches are built, the aproximate volume of water which each new channel will carry. As has been stated the formula most generally used for this purpose is that of Kutter's. But Kutter's formula will give results either too great or too small in proportion as one chooses too low or too high a value for the coefficient of roughness (n).

The experiments made in the past to determine the values of (n) for canals have been largely confined either to new channels or to conditions somewhat different from those which prevail in Western America. In the case of new canals it is believed that the coefficient of roughness of the wetted surface is much greater than it is in canals of similar form and materials when the wetted surface is well coated with fine sediment.

The friction, too, seems to depend quite as much on how the particles of gravel and cobble rock are packed as on their size. Again the effects of water plants in retarding the velocity of water in canals have been usually considered less than these experiments would seem to show.

On account of the dissimilarity between the physical conditions of the channel from which the present values of (n) have been derived and the ditches and canals of irrigated America, the writer has attempted in the accompanying table to assign values for (n) which would be more in accordance with the conditions which now exist in the Rocky Mountain States. Future experiments in which the details are more accurately conducted may, however, modify the values of (n) as here given.

Values of (n) for Irrigation Ditches and Canals.

N=.0175 for canals in earth in excellent condition, well coated with sediment, regular in cross section and free from vegetation, loose pebbles and cobble rock.

N=.020 for canals in earth in good condition lined with well packed gravel partly covered with sediment and free from vegetation.

N=.0225 for canals in earth in fair condition, the wetted surface being lined with sediment with an occasional patch of low water plants, or composed of loose gravel without vegetation.

N=.0250 for canals in earth in average condition having few sharp bends and being fairly uniform in cross-section; the water slopes and bottom being lined with sediment and low water plants, or composed of loose gravel and fragments of rock less than two inches in diameter and free from vegetation.

N=.0275 for canals in earth below the average in grade, alignment and cross-section; having indentations on the sides, the edges in places partially filled with earth and gravel and the lining composed of coarse gravel and cobble rock unpacked. This value would also apply to a smooth regular surface if the channel were partially filled with aquatic plants.

N=.0300 for canals in earth in rather bad condition having the bed partially covered with debris; or having comparatively smooth sides and bottom with bunches of grass and weeds projecting into the water and more or less aquatic plants growing in the channel.

N=.0350 for small ditches having a small uneven bed and for canals in earth in fairly good condition but partially filled with aquatic plants.

N=.040 for canals in earth whose channels are about half full of aquatic vegetation.

N=.050 for canals in earth whose channels are about two-thirds full of aquatic vegetation.

From the experiments on the flow of water in irrigation ditches and canals herein briefly described the facts there presented would seem to justify the author in drawing the following conclusions:

(1) That sections of canals in earth, although carefully built of a trapezoidal form, with the bottom width horizontal, soon change to segments ressembling those of an ellipse

(2) That in all large or medium sized canals in earth, berms are necessary in order to prevent a portion of the excavated material from rolling into the canal.

(3) The carrying capacities of new irrigation canals and ditches during the first season of their operation are less than in subsequent seasons, providing the same conditions are maintained.

(4) The coefficient of friction in canals well lined with sediment in good order and long in use is less than has been usually supposed.

(5) The frictional resistance of coarse materials, such as gravel, pebbles or cobble rock, depends to a large extent on whether such material is well packed or loose.

(6) That a rough channel exerts a greater influence in retarding the flow of a small ditch than the same degree of roughness exerts on the large canal or river.

(7) In the past, canal builders have to a great extent overlooked the injurious effects of the growth of aquatic plants.

(8) The effect of water plants in checking the flow and lessening the capacity of irrigation canals may be much greater than a rough uneven channel

(9) In parts of the arid West where such vegetation grows abundantly the canals should be built in such a way as to prevent its growth, or, if this is impracticable, to facilitate its removal.